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PROCESS FOR BONDING WOOD BASE ELEMENTS TO PLASTIC

The invention relates to a process for bonding wood base elements to plastic, in particular for production of functional elements, by means of an injection-molding process in which the wood base element is inserted into an injection mold and, at the previously selected sites, plastics melt is injected and irreversibly changes the shape of the wood base element.

In conventional products which are composed of wood and plastic and in which the plastics constituent is produced by the injection-molding process, the bond between wood and plastic is produced via adhesion at the interface and/or via undercuts or the like previously created mechanically on the wood base part. It is known that wood/plastics laminates can be produced via injection-molding methods of reverse- or top-coating, or by injection-molding of plastic around components, or by injection-molding of plastics functional elements on wood base parts, for example for production of snap hooks, protective coatings, wear-resistant surfaces, and the like.

As an alternative to this it is known that wood can be bonded to polymeric materials via gluing, impregnation, and adhesive bonding, reactively, or by means of screw threads and nails. Screw threads and nails here are

connecting elements which are not appropriate for the anisotropy of wood and therefore impair the strength of the bond.

An object on which the invention is based is to bond wood base elements to plastic by means of an injection-molding process with formation of a plastics part, in such a way that the strength and the durability of the bond exceed those from known methods. The process is moreover intended to permit creation of this bond in a single operation. The process is also to cover a wide variety of application sectors in which a composite composed of wood with plastic can advantageously be utilized as a material.

The object set is achieved according to the invention in that the plastics melt forms depressions acting in the manner of undercuts on the surface of the wood base element.

The inventive process therefore utilizes the anisotropic structure naturally present in wood, in that the wood structure is intentionally partially disrupted, in particular deformed, expanded, or the like, in order that at these sites the plastics melt and finally the hardened plastics material can bond securely and durably to the wood. In this process, the plastics melt forms depressions acting in the manner of undercuts on the wood base element. These depressions arise especially at sites at which pressure is exerted perpendicularly to the longitudinal direction of the wood fibers during the injection-molding process. This is one

way of producing a very firm bond of the plastics part to the wood base part.

During the injection-molding process, the injection pressure prevailing forms available spaces in or on the wood component. The plastics melt thus produces depressions which it fills, and plastics melt pressed into the wood forms embedments. Higher pressures enlarge the flow cross section. In the inventive process there is no requirement for application of mechanical undercuts or for preparative mechanical treatment of the wood insert part. Those properties of the wood component which are relevant and specific to the application are retained in full. The position of those regions of the wood insert part which are intended to be depressed by plastic or through which plastic is intended to flow can be prescribed previously during a design process. Controlled influence can be exerted over these regions via the selection of the type of wood, via the selection of the plastics material, via the geometry of the insert part, via the geometry of the mold cavity, and also via the process parameters.

In the inventive process, the plastics embedments and/or the plastics-filled depressions and the like are formed at sites on the wood base element which have previously been specified during a design process. This permits avoidance of embedments of plastic on the wood base element at sites where they would not be desired.

The inventive process permits production of components in which the plastics melt forms a visible protrusion of injected material at the outer side. However, it is also possible to produce parts via injection molding onto the wood base element with no protrusion of injected material.

An advantageous injection pressure for forming depressions and embedments on the wood base element is in the range from 10 bar to 2500 bar. The mold cavity pressure is from 50 bar to 1400 bar.

The conventional plastics for injection-molding processes can be used as plastics material. The plastic can therefore in particular be a thermoplastic, whereupon the temperature of the plastics melt is selected to be from +130°C to +400°C.

As an alternative to this, it is also possible to use a reactive plastic, such as an elastomer. In this instance, the temperature of the flowable plastic can even be room temperature, or can be above room temperature.

Undesired thermal disruption of the wood base element is avoided not only via the temperature selected for the plastics melt but also via the injection time for the plastics melt. This injection time is selected to be in the range from a few tenths of one second to a few seconds. Particularly suitable types of wood for the wood base element are balsa, spruce, oak, or beech, but other types of wood

whose property profile is at least substantially the same as that of the types of wood mentioned also have good suitability.

The inventive process can, as a function of the process parameters selected, create depressions and/or embedments whose linear dimension is from about 1 mm to two or more centimeters in the wood base element.

The invention further provides a wood-plastic composite component which has been produced by the inventive process. These wood-plastic composite components are preferably sports equipment, an office requisite, a window, a door, an item of furniture, a floor covering, a toy, a packaging product, a machinery component or a vehicle component, a musical instrument, a hand tool, or the like.

The invention is now described in more detail on the basis of the drawing, which gives diagrams of a number of inventive examples.

Fig. 1 shows an axial longitudinal section through a grip element, and

fig. 2 shows an oblique view of the grip element,

fig. 7 shows an axial longitudinal section through a screw-thread mandrel, and

fig. 8 shows an oblique view of the screw-thread mandrel,

fig. 14 shows a partial section through a connector part, and

fig. 15 shows an oblique view of the connector part,

fig. 16 shows a partial section through another embodiment of a connector part,

and fig. 17 shows an oblique view of this connector part.

The invention provides processes for bonding of wood to a plastic by means of injection molding. A long-lasting bond is achieved in various ways between the plastics part molded during and by means of the injection-molding process and the wood base part, as is now explained in further detail on the basis of the figures in the drawing.

In all of the embodiments, the components are combinations composed of base elements composed of wood with plastics functional elements. In the sections shown, the drawings have lines (hatching) on the wood constituents in the longitudinal direction of the wood fibers, and the functional elements composed of plastic have been shown by intersecting lines in the sections shown. The drawings have more densely intersecting lines in those regions in the wood components which are the regions of bonding of the wood base element to the plastics material of the plastics functional elements.

During production of the plastics part, the interfaces between the wood base part and the plastics part to be formed are selected in such a way as to permit, by virtue of the preferential direction of the wood fibers and by virtue of the geometry of the wood insert part, depression of the wood and/or penetration of the plastics melt into the wood part. The injection mold here can be designed in such a way, and the plastic here can be introduced into the mold in such a way, that the injected material either protrudes at least to some extent at the outside of the wood insert part or, if this is to be avoided, that the wood base part is pressed onto the mold wall and onto the mold cavity in such a way as to prevent protrusion of injected material from the outside.

Fig. 1 shows one of the inventive ways of injection molding a plastics part around a wood base part and for bonding of these, where, at a site specified during a design process, the plastic produces a depression in the wood in a manner which is intentional, irreversible, and at the same time disruptive. Production of the depression produces at least one undercut which produces the bond. As figs. 1 and 2 show, the component produced according to the invention is a grip element 1, which is composed of a cylindrical wood shaft 2 and of a plastics cap 3 which sheathes one of the end regions of the wood shaft 2 and has been applied by injection-molding of one material around the other. As is

clear from the longitudinal section shown in fig. 1, two depressions 2a are produced during the injection-molding procedure via pressure exerted perpendicularly to the longitudinal direction of the fibers. The depressions 2a act as undercuts and hold the plastics cap 3 securely on the wood shaft 2.

The screw-thread mandrel 11 shown in fig. 7 and fig. 8 likewise has a cylindrical wood shaft 12 and, injection-molded onto one end, a plastics part 13 provided externally with a screw thread. One end of the wood shaft 12 has been provided with a hole 12a which during the injection-molding procedure becomes filled with plastic. Again in the case of this embodiment, the above-mentioned process parameters - pressure, temperature, time - are selected in such a way during the injection-molding of the plastics part 13 that plastics embedments 15 form from the base of the hole 12 in the longitudinal direction of the shaft and therefore in the direction of the wood fibers, and depressions 15a form along the walls of the hole 9.

Figs. 14 and 15 show a connector 28, as can by way of example be used when connecting furniture components composed of wood. The base part 29 composed of wood is provided with a recess in which a plastics connector part 30 is formed via injection molding. The connector part 30 is formed with receptor sites 31 whose shape is swallow-tailed in cross section, so that elements of equivalent but opposite design

on a second component not shown can be inserted in a manner which reliably prevents release. Fig. 14 shows a section through the wood component 29. During the injection-molding procedure, the plastics melt has formed embedments 32 in the direction of the fibers of the wood component 29, and depressions 32a perpendicularly to the direction of running of the fibers.

Figs. 16 and 17 likewise show a versatile component 33 composed of wood, these having been provided with plastics connectors 35 produced via injection-molding onto the wood component 33, 34. In addition, a receptor hole 37 has been created in the wood component 33 and is lined with plastics material, and can also have an internal screw thread. During the injection-molding procedure, embedments 39 have formed in the direction of the wood fibers, extending into the wood material. The plastics melt has produced depressions 41 on the outer side of the structure shown in fig. 16.

The positions of those regions of the wood insert part in the injection mold which are depressed by or penetrated by the plastics melt have been prescribed in a design process. The production of embedments or depressions can be influenced via the selection of the type of wood and of the plastic, via the geometry of the wood insert part and via the geometry of the mold cavity, which corresponds to the geometry of the plastics part to be formed, and also via the process parameters. As already mentioned more than once, the

substantial process parameters - pressure (injection pressure in the system), temperature of the plastics melt, and injection time - are selected during the injection-molding process in such a way that, as a function of the nature of the wood base part, the wood structure is partially expanded via penetration of the plastics melt, or depression and production of depressions takes place at the surface. This process utilizes the anisotropic structure of wood. The available spaces formed via the injection pressure in the wood therefore bring about distribution of the flowable plastic, and the flow cross section can be enlarged here via higher pressures.

When the injection-molding procedure forms, in the wood component, depressions, areas of deformation, embedments, or regions where the plastics melt fully penetrates the wood material, these may have various dimensions. The depth of penetration can extend from about 1 mm to 2 or more centimeters. This depth of penetration is therefore about one order of magnitude greater than the values typical for gluing.

A preferred suitable plastics material is a thermoplastic which in the form of flowable melt is injected with a defined period of exposure to pressure, and at an appropriate temperature, within a mold, onto the wood base part inserted into the mold, and solidifies via cooling in the mold. The plastic can also be a reactive material, such

as an elastomer, which in a manner identical to that for a thermoplastic melt, is injected into the mold, but solidifies via reaction. The plastic can be introduced by the compact injection-molding process and/or by a specialized injection-molding process, such as injection-compression molding, multicomponent injection molding, decorative reverse-coating by an injection-molding method, gas-injection technology, and the like.

As mentioned above, the invention utilizes the anisotropic structure of wood. As is known, wood is mostly composed of cells known as tracheas (fibers), arranged in the tree in the direction of growth. They are held together via an amorphous matrix which is rich in lignin. The length of the tracheas is from 2 mm to 4 mm and their length/diameter ratio is 100:1. The strength of the fibers themselves is up to five times higher than that of the entire composite. The strength of the matrix is therefore correspondingly smaller.

Wood and plastic are broadly related organic materials with different properties, and can be particularly advantageously combined via the inventive method of bonding. By way of example, wood has high values for strength and stiffness in its preferential direction (direction of growth), based on its density. Transversely to the preferential direction, the level of these properties is markedly lower. Plastic has advantages in the formation of functional geometries, use of plastic permitting formation of

even very fine elements, and its material behaves substantially isotropically, absorbs little or no moisture, and can be rendered highly flexible, even elastomeric. Other advantages are good weathering resistance and chemicals resistance.

The table below states some characteristic types of wood particularly suitable for the inventive process with their density and with some strength values in the direction of the fibers, but it is also possible to use other types of wood whose property profile is similar:

Type of wood	**Density g/cm^3**	**Tensile strength N/mm^2**	**Compressive strength N/mm^2**	**Flexural strength N/mm^2**
Balsa	0.05 - 0.13	20 - 40	5 - 15	15 - 23
Spruce	0.40 - 0.50	80 - 90	40 - 50	65 - 77
Oak	0.75 - 0.85	90 - 110	52 - 64	90 - 110
Beech	0.65 - 0.95	100 - 140	52 - 82	90 - 160

The injection pressure in the injection-molding machine is set within the range from 10 bar to 2500 bar. Typical mold cavity pressures for the process are from 50 bar to 1400 bar. This is within and markedly above the range of compressive strengths of wood ($1\ N/mm^2 = 10$ bar). Cavity pressures of this order of magnitude therefore permit intentional, controlled, partial disruption or deformation of

the wood structure. In comparison with this, the pressures during injection molding are markedly lower, being from 10% to at most 20% of the values given for injection molding.

The insert part composed of wood can be surface-pretreated after trimming to size and prior to insertion into the mold, and this can be a manual or automatic process. Roughening, staining, etching, washing, mechanical operations via grinding, milling, or production of holes, etc. are possible. In order to distribute the plastics melt, preformed holes and/or grooves can be provided, but this is not essential.

Introduction or penetration of embedding compositions at relatively low and moderate pressures at about 10 bar, at most 50 bar, into existing cavities of the wood, such as cracks, perforations, etc. in presses is not the same as the inventive process. Specifically, these cavities are previously present in the wood. In the inventive process, the existing structure of the wood is partially expanded or deformed via higher pressure, thus creating the spaces available for the bonding process for the plastics material.

During the injection molding of thermoplastics, the temperatures for the melt are selected to be in the range from +130°C to 400°C. Reactive plastics, such as elastomers, are also processed at temperatures lower than this, down to room temperature. Although the temperature of the plastics melt is mostly above that of the thermal stability limit of

wood, which is about +180°C, short injection times of from a few tenths of one second to a few seconds can avoid subsequent thermal degradation. Brief intensive contact is advantageous for the bonding process, however. Because wood is a comparatively good thermal insulator, only the uppermost layers in the region of the contact area are affected by exposure to relatively high temperatures. In contrast, the press procedures used in production of composite sheets composed of wood take a number of minutes, indeed up to hours in the case of cold pressing. The process temperature during the pressing process cannot therefore be allowed to exceed the thermal stability limit.

Possible application sectors for production of components by the inventive process are any of the application sectors in which wood can be utilized as a material. Other examples besides the examples in the figures of the drawing are sports equipment, such as skis, for integration of binding elements, office requisites, such as stationery requisites, windows and doors - for example connecting and functional elements applied by injection molding, e.g. hinges, etc. - furniture - in particular connecting elements - floor coverings, in particular parquet with snap connectors, toys and consumer equipment, e.g. connections unaffected by moisture for wooden handles and for tools, wood parts bonded by means of plastics elements and moved with respect to one another, for example in the manner

of Matador or Lego. Other application sectors are spring-and-damper systems, means of transport, and packaging, such as pallets composed of wooden boards bonded with plastic, container lids onto which film hinges have been injection molded, and also components of machinery and of vehicles, e.g. sliding shoes, brake linings, bearing shells, friction wheels, V-belt pulleys, running wheels, support elements, and also functional elements of musical instruments, and the like.